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UNITED STATES PATENT APPLICATION

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RFID TAG WIDE BANDWIDTH LOGARITHMIC SPIRAL ANTENNA METHOD AND SYSTEM

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CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of U.S. Provisional Patent Application Serial No. 60/412,526, which was filed on 09/20/2002, of common title and inventorship with the present applications, and which application is hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to radio frequency identification (RFID), and more particularly to wide bandwidth spiral antennas, radio frequency (RF) transponder tag circuitry and impedance matching networks.

Background Information

Radio frequency identification (RFID) is well known using 125KHz and 13.56 MHz for passive and active transponders, respectively. A passive transponder accepts power from the received signal and returns an identification signal. Active transponders contain a power source and need not be powered from the received signal. Therefore passive transponders require higher signal strength, while active transponders require much less signal strength, but at the cost of a power source.

Another area of concern is the Federal communications commission (FCC) regulates emissions, so prior art designs provide high power at short range but employ canceling techniques to comply with far range FCC regulations.

RFID tag installations now in use have ranges of about thirty inches, that are typically found in retail stores. Circuits with greater range have been investigated, especially transponders in the 900 MHz to 2.50 GHz range. A company named Intermec, sells an expensive 915 MHz tag system.

U.S. patent no. 6,118,379 ('379) to Kudukula et al and U.S. patent no. 6,285,342 B1 ('342) to Brady et al. are two patent is this field.

The '379 patent uses a partial spiral (one arm) with a spaced ground plane and claims maximum range in its abstract. A carrier frequency of 2.45 GHz is discussed but the range appears to be in the range of inches. Moreover, the partial spiral limits bandwidth, which is desired in this patent, and the spaced ground plane adds cost. The '342 patent uses a distorted spiral to gain a larger antenna in a button sized package and also uses a loading bar and stubs to match impedances, but adds complexity and cost, but does not appear to extend the useable range beyond the above mentioned thirty inches.

There is a need for RFID systems for tracking cattle, baggage transponders, car or such vehicle identification, and warehouse tracking. Such systems will require RFID systems with a range in the order of ten feet. There is also a need to meet the requirements of both the United States and Europe for such RFID systems. The U.S. systems operate at 915 MHz and similar Europe systems operate at 869 MHZ. To meet both such standards at a range of ten feet, an RFID tag system would need an improved antenna and a relatively wider bandwidth than known prior art systems.

An article in Applied Microwave & Wireless, entitled: "A Logarithmic Spiral antenna for 0.4 to 3.8 GHz," by Jesper Thaysen et al, describes a spiral antenna mounted with a balun and a cavity. This article presents some technical discussion relevant to the general field of spiral antennas and is hereby incorporated herein by reference. The article is silent on applications. From Figure 1 in the article, a co-ax connector is shown relative to the spiral arms. From this figure and assuming that co-ax is about 1/3 to ½ inches wide, the distance between the most distant points on the spiral arms is estimated to be at least 16 inches. Clearly this antenna is not suited for RFID applications.

It is an objective of the present invention to provide a longer range, more than ten feet, RFID tag system with the small tag form factor that meets the requirements of Europe and the U.S.

SUMMARY OF THE INVENTION

In view of the foregoing background discussion, the present invention provides an RFID tag antenna system with two symmetrical placed identical planar arms arranged in a spiral where the width of the arms grow as the arms radiate away from a center. The growth of the arms, preferably, provide for equal widths and spaces at equal distances from the center. The growth of the widths of the arms is arranged by defining an inner and an outer radial spiral according to logarithmic functions.

The antenna system is preferably flexibly arranged to fit within a tag form factor that is determined from the application.

In a preferred embodiment, there is an impedance matching network that is packaged on the same substrate as the planar spiral antenna. An input circuit is preferable provided on a separate substrate that is joined to the antenna bearing substrate forming a sandwich package that maintains the tag form factor. Rectifying Schottky diodes form part of the input circuit to form a DC signal. The input circuit, in a preferred embodiment may includes a capacitor built into the die as is known in the art (say a reversed biased diode) to store charge from the DC signal when the RF signal is strong. The charge on such a capacitor can be used so that the tag circuit will respond when the input RF signal is lower.

Typically, the presence of the tag is sensed by noting the increased power supplied by an RF sending or interrogating station.

Preferably the antenna arms are formed by etched copper runs on a substrate, and/or by using conductive paints or other conductive metals, like silver, aluminum or solder. The arms define a center where the two arms define a gap, the closest point to each other. The matching network is connected at this gap to the antenna arms.

It will be appreciated by those skilled in the art that although the following Detailed Description will proceed with reference being made to illustrative embodiments,

the drawings, and methods of use, the present invention is not intended to be limited to these embodiments and methods of use. Rather, the present invention is of broad scope and is intended to be defined as only set forth in the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention description below refers to the accompanying drawings, of which:

FIG. 1 is a system block diagram of an RFID tag system,

FIG. 2 is frequency chart of a preferred embodiment for a transponder suitable for being read in Europe and in the U.S.;

FIG. 3 is a graph of one leg of a preferred spiral antenna;

FIG. 4 is a circuit diagram of the impedance matching network of a passive transponder;

FIG. 5 are the calculations for a preferred embodiment, and

FIGS. 6A and 6B are illustrations of a full spiral antenna, matching network and input circuitry built in accordance with the present invention.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

FIG. 1 is a basic block diagram of an illustrative RFID tag system. Here an interrogation station 100 generates an RF signal 108, usually a pulse signal generated by the logic circuit 104, that is transmitted 110 via an antenna 112 to a tag system 102. The RF pulse is received via an antenna 114 and an RF impedance matching circuit 116 as is known in the art, and, an input circuit 118. If the RF signal is strong enough, the input circuitry rectifies the RF signal and charges a capacitor is used to power the tag system when the RF signal is low. As is known in the art, the tag circuit presents a load to the RF transmitter causing the RF transmitter power to increase in the presence of a tag. In one embodiment , as known in the art, the driving RF voltage signal is stepped up. That increase may be sensed by the logic circuitry 104 to indicate the presence of the tag. Other known techniques may used to generate and detect a tag.

FIG. 2 shows a frequency response for a transponder suitable for operating in Europe and in the U.S. The 915 MHz representing the U.S. frequency of choice and the 869 MHz Europe's. At these frequencies the U.S. allows a maximum of 1 watt power output from the reader while Europe's maximum is 0.5 watt at 869 MHz.

The antenna, by inspection of FIG. 2, to meet these two requirements requires a bandwidth of 47 MHz with a Q of 19. Such a system may be deployed, but is not limited thereto, in a luggage tag system that passes both U.S. and European standards.

FIG. 3 shows one arm of a spiral antenna with the outer spiral radius r1 200 created in accordance with $r1 = r0e^{a\theta}$ and the inner spiral radius r2 202 created on accordance with $r2 = r0e^{\theta-\theta 0}$. Here r0 represent an initial position, θ angular position, θ0 the angular offset between r1 and r2, and "a" growth rate.

A second arm (shown in FIG. 6) can be created by rotating the one arm by 180 degrees in the plane of the one arm. A small gap is left between the two spiral arms at their starting points. Impedance matching circuitry of FIG. 4 is applied to this gap. To achieve frequency independence of the antenna the widths of the arms are made equal to the spacing between the arms as the arms radiate and grow outward.

FIG. 4 illustrates one example of an antenna 300 measured with an impedance of 16-j10 at 915 MHz and an impedance matching circuit network 302. The resistor R1 and capacitor C1 represent the impedance of the antenna not actual components. The matching circuit network 302 nulls out the capacitive reactance of the antenna impedance. The resistive element is stepped up by the 3 K ohm resistor at the input circuitry side and used for charging the capacitor C3. The die input circuitry 304 includes two Schottky diodes, resistor R2, and a capacitor C3. Diode D1 clamps the voltage negatively with D2 operating as a peak detector in the forward direction to provide a DC voltage/current to charge up the capacitor C3. The charged capacitor powers the device when receiving low amplitude pulses from the reader, for example when the reader is distant.

The die input circuitry 304 is so called since in a preferred embodiment it is packaged on a separate die that is mounted onto a substrate carrying the antenna and the matching network.

FIG. 5 shows the applicable calculations for a specific preferred embodiment of the RFID tag system operating at 915 MHz..

FIG. 6A shows a preferred embodiment of a substrate of the present invention spiral antenna arms 500, 502. The spiral arms are built using 2 mil copper tape and conductive paint on a 5 mil thick polyimide substrate 504. The substrate is about 59 mm or 2.32 inches wide by 40 mm or 1.57 inches. The two symmetrical arms are shown 500 and 502, and the matching circuit network 302 is built on the substrate. The die input circuitry 304 is attached, see FIG. 6B, by raised solder balls, like in a ball grid array IC package. Of course other attachment methods may be used including building the die input circuitry onto the antenna substrate. In one preferred example, the capacitor C3 of FIG. 4 operating at 915 MHz builds a charge to 3.9 volts. The read distance using a linearly polarized reader RF signal is twelve feet, and six feet with a circularly polarized reader RF signal.

In the preferred embodiment illustrated of FIG. 6A, the linear dimensions of the spiral antenna itself is less than about 2.3 inches wide 508 by less than about 0.8 inches high 510.

FIG. 6B illustrates a preferred embodiment where a second substrate 520 carrying the die input circuitry 304 makes electrical connections to the matching network via the nodes or ball 506.

It should be understood that above-described embodiments are being presented herein as examples and that many variations and alternatives thereof are possible. Accordingly, the present invention should be viewed broadly as being defined only as set forth in the hereinafter appended claims.

What is claimed is: